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Distribution System Supply Voltage Quality

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NATIONAL FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Basic Electrotechnical Standards and Power Quality Sectional Committee had been approved by the Electrotechnical Division Council.

This standard specifies the main characteristics of the voltage at network user's supply terminals in distribution system. The characteristics of the supply voltage considered by this standard are:

a) Frequency;
b) Magnitude;
c) Waveform; and
d) Symmetry of the line voltages.

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated expressing the result of a test or analysis shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding of numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

DISTRIBUTION SYSTEM SUPPLY VOLTAGE QUALITY

1 SCOPE

1.1 This Standard specify the main characteristics of the voltage at network user's supply terminals in distribution system.

1.2 The characteristics of the supply voltage considered by this standard are:

a) Frequency;
b) Magnitude;
c) Waveform; and
d) Symmetry of the line voltages.

1.3 This Standard applies only under normal operating conditions and in the case of compliance of a network user's installation or equipment with:

a) The relevant standards;
b) The technical requirements for connection, established by the distribution licensee; and
c) The limits for the emission of conducted disturbances.

2 REFERENCES

The standards given below contain provisions which, through reference in this text, constitute provision of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreement based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

IS No./ Other Publication	*Title*
IS 12360 : 1988	Voltage bands for electrical installations including preferred voltages and frequency
EN 50160 : 2010	Voltage characteristics of electricity supplied by public distribution systems
IEC 61000-2-2 : 2002	Electromagnetic compatibility (EMC) — Part 2-2: Environment — Compatibility levels for low-frequency conducted disturbances and signaling in public low-voltage power supply systems
IEC 61000-2-8 : 2002	Electromagnetic compatibility (EMC) — Part 2-8: Environment — Voltage dips and short interruptions on public electric power supply systems with statistical measurement results
IEC 61000-4-30 : 2015	Electromagnetic compatibility (EMC) — Part 4-30: Testing and measurement techniques — Power quality measurement methods

3 TERMS AND DEFINITIONS

For the purposes of this document, the following terms and definitions apply.

3.1 Conducted Disturbances

Electromagnetic phenomenon propagated along the line conductors of a distribution system.

NOTE — In some cases an electromagnetic phenomenon is propagated across transformer windings and hence between networks of different voltage levels. These disturbances may degrade the performance of a device, equipment or system or they may cause damage.

3.2 Declared Supply Voltage (Uc)

Declared supply voltage, Uc shall be the voltage at the consumers supply terminals declared by the supplier of electrical energy. Uc is usually equal to the nominal voltage, Un.

NOTE — Declared supply voltage, Uc is usually equal to the nominal voltage Un but it may differ by agreement between the network user and the network operator.

3.3 Flicker

Impression of unsteadiness of visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates with time.

NOTE — Flicker is caused under certain conditions by voltage fluctuation changing the luminance of lamps.

3.4 Flicker Severity

Intensity of flicker annoyance evaluated by the following quantities:

a) Short term severity (P_{st}) measured over a period of 10 min;

The measure of severity based on an observation period T_{short} = 10 min is designated P_{st} and is derived from the time-at-level statistics obtained from the level classifier in block 5 of the flicker meter. The following formula is used:

$$P_{st} = \sqrt{0.031\,4\,P_{0.1} + 0.052\,5\,P_{1s} + 0.065\,7\,P_{3s} + 0.28\,P_{10s} + 0.08\,P_{50s}}$$

Where, the percentiles $P_{0.1}$, P_1, P_3, P_{10} and P_{50} are the flicker levels exceeded for 0.1; 1; 3; 10 and 50 percent of the time during the observation period. The suffix "s" in the formula indicates that smoothed values should be used; these are obtained using the following equations:

$$P_{50s} = (P_{30} + P_{50} + P_{80})/3$$

$$P_{10s} = (P_6 + P_8 + P_{10} + P_{13} + P_{17})/5$$

$$P_{3s} = (P_{2.2} + P_3 + P_4)/3$$

$$P_{1s} = (P_{0.7} + P_1 + P_{1.5})/3$$

The 0.3 s memory time-constant in the flicker meter ensures that $P_{0.1}$ cannot change abruptly and no smoothing is needed for this percentile.

NOTE — The P_{st} value is a mandatory output, while outputs for the individual values of the percentiles are optional.

b) Long term severity (P_{lt})

Long term severity level, denoted by $P_{lt,}$ is calculated for a two hour period. It is derived as follows from the values of P_{st} for 12 consecutive 10 min period:

$$p_{lt} = \sqrt[3]{\sum_{i=1}^{12} \frac{P_{sti}{}^{3}}{12}}$$

Where, P_{sti} (i = 1, 2 ....12) are 12 consecutive values of P_{st}.

3.5 Frequency of the Supply Voltage

Repetition rate of the fundamental wave of the supply voltage measured over a given interval of time.

3.6 Harmonic Voltage

Sinusoidal voltage with a frequency equal to an integer multiple of the fundamental frequency of the supply voltage.

NOTES

1 Application: Harmonic voltages can be evaluated:

a) Individually by their relative amplitude (u_h) which is the harmonic voltage related to the fundamental voltage (u_1), where h is the order of the harmonic; and

b) Globally, for example by the total harmonic distortion factor THD, calculated using following expression:

$$THD = \sqrt{\sum_{h=2}^{50} (u_h)^2}$$

2 Harmonics of the supply voltage are caused mainly by network users' non-linear loads connected to all voltage levels of the supply network. Harmonic currents flowing through the network impedance give rise to harmonic voltages. Harmonic currents and network impedances and thus the harmonic voltages at the supply terminals vary in time.

3.7 High Voltage (HV)

Voltage whose nominal root mean square (r.m.s.) value is 33 < Un ≤ 150 kV.

3.8 Medium Voltage (MV)

Voltage whose nominal r.m.s. value is 1 kV <Un ≤ 33 kV.

3.9 Low Voltage (LV)

Voltage whose nominal r.m.s. value is Un ≤ 1 kV.

3.10 Mains Signaling Voltage

Signal superimposed on the supply voltage for the purpose of transmission of information in the distribution system and to network users premises.

NOTE — Three types of signals in the public supply network can be classified:

a) Ripple control signals: superimposed sinusoidal voltage signals in the frequency range 110 Hz to 3 000 Hz;

b) Power-line-carrier signals: superimposed sinusoidal voltage signals in the frequency range 3 kHz to 148.5 kHz;

c) Mains marking signals: superimposed short time alterations (transients) at selected points of the voltage waveform.

3.11 Network User

Party, being supplied by or supplying to an electricity supply distribution network.

3.12 Distribution Network Licensee

Party responsible for operating, maintaining and developing the supply network for ensuring its long term ability to meet expected demands for electricity supply and standards of performance as specified by Appropriate State Electricity Regulatory Commission.

3.13 Nominal Frequency (of the Distribution System)

Nominal value of the frequency of the supply voltage.

3.14 Normal Operating Condition

Operating condition for an electricity network, where generation and load demands meet, system switching operations are concluded, faults are cleared by automatic protection systems and in the absence of:

a) Temporary supply arrangement;

b) Non-conformity of a network user's installation or equipment with the relevant standards or with the technical requirements for connection; and

c) Exceptional situations, such as:

    1) Exceptional weather conditions and other natural disasters;
    2) Force majeure;
    3) Third party interference;
    4) Acts by public authorities;
    5) Industrial actions (subject to legal requirements); and

6) Power shortages resulting from external events.

3.15 Nominal Voltage (of the Distribution System) Un

Value of voltage by which the electrical installation or part of the electrical installation is designated and identified.

3.16 Rapid Voltage Change

Single rapid variation of the root mean square (r.m.s.) value of a voltage between two consecutive levels which are sustained for definite but unspecified durations.

3.17 Reference Voltage (for Interruptions, Voltage Dips and Voltage Swells Evaluation)

Value specified as the base on which residual voltage, thresholds and other values are referred in per unit or percentage terms.

NOTE — For the purpose of this standard, the reference voltage is the nominal or declared voltage of the supply system.

3.18 Residual Voltage (U_{res})

Minimum value of U_{rms} (½) recorded during a voltage dip or interruption .

3.19 Supply Interruption

Condition in which the voltage at the supply terminals is lower than 5 percent of the reference voltage.

NOTE — Supply interruptions can be classified as:

a) Pre-arranged, when network users are informed in advance; or

b) Accidental, caused by permanent or transient faults, mostly related to external events, equipment failures or interference. An accidental interruption is classified as:

1) A long interruption (longer than 3 min),

2) A short interruption (upto and including 3 min),

3) For polyphaser systems, an interruption occurs when the voltage falls below 5 percent of the reference voltage on all phases (otherwise, it is considered to be a dip).

3.20 Supply Terminal

Point in a distribution system designated as such and contractually fixed, at which electrical energy is exchanged between network user and distribution network licensee.

NOTE — This point can differ from the electricity metering point or the point of common coupling.

3.21 Supply Voltage

Root mean square (r.m.s.) value of the voltage at a given time at the supply terminal, measured over a given interval.

3.22 Transient Overvoltage

Short duration oscillatory or non-oscillatory overvoltage usually highly damped and with a duration of a few milliseconds or less.

NOTE — Transient over voltages are usually caused by lightning, switching or operation of fuses. The rise time of a transient overvoltage can vary from less than a microsecond up to a few milliseconds.

3.23 Voltage Dip

Temporary reduction of the root mean square (r.m.s.) voltage at a point in the electrical supply system below as specified start threshold.

NOTES

1 Application: For the purpose of this standard, the dip start threshold is equal to 90 percent of the reference voltage.

2 Typically, a dip is associated with the occurrence and termination of a short circuit or other extreme current increase on the system or installations connected to it.

3 For the purpose of this Standard, a voltage dip is a two dimensional electromagnetic disturbance, the level of which is determined by both voltage and time (duration).

3.24 Voltage Dip Duration

Time between the instant at which the root mean square (r.m.s.) voltage falls below the start threshold and the instant at which it rises to the end threshold.

NOTES

1 Application : For the purpose of the standard, the duration of a voltage dip is from 10 ms up to and including 1 min.

2 For polyphase events, a dip begins when one voltage falls below the dip start threshold and ends when all voltages are equal to or above the dip end threshold.

3.25 Voltage Dip End Threshold

Root mean square (r.m.s.) value of the voltage on an electricity supply system specified for the purpose of defining the end of a voltage dip.

3.26 Voltage Dip Residual Voltage

Minimum value of root mean square (r.m.s.) voltage recorded during a voltage dip.

NOTE — For the purpose of this Standard, the residual voltage is expressed as a percentage of the reference voltage.

3.27 Voltage Dip Start Threshold

Root mean square (r.m.s) value of the voltage specified for the purpose of defining the start of a voltage dip.

3.28 Voltage Fluctuation

Series of voltage changes or a cyclic variation of the voltage envelope.

3.29 Voltage Swell (Temporary Power Frequency Overvoltage)

Temporary increase of the root mean square (r.m.s.), voltage at a point in the electricity supply system above a specified start threshold.

NOTES

1 Application: For the purpose of this Standard, the swell start threshold is equal to 110 percent of the reference voltage.

2 For the purpose of this Standard, a voltage swell is a two dimensional electromagnetic disturbance, the level of which is determined by both voltage and time (duration).

3 Voltage swells may appear between live conductors or between live conductors and earth. Depending on the neutral arrangement, faults to ground may also give rise to over voltages between healthy phases and neutral.

3.30 Voltage Swell Duration

Time between the instant at which the root mean square (r.m.s) voltage at a particular point of an electricity supply system exceeds the start threshold and the instant at which it falls below the end threshold.

NOTE — Application for the purpose of this standard, the duration of a voltage swell is from 10 mins up to and including 1 min.

3.31 Voltage Swell End Threshold

Root mean square (r.m.s.) value of the voltage on an electricity supply system specified for the purpose of defining the end of a voltage swell.

3.32 Voltage Swell Start Threshold

Root mean square (r.m.s.) value of the voltage on an electricity supply system specified for the purpose of defining the start of a voltage swell.

3.33 Voltage Unbalance

Condition in a polyphase system in which the root mean square (r.m.s.) values of the line-to-line voltages (fundamental component), or the phase angles between consecutive line voltages, are not all equal.

NOTES

1 The degree of inequality is usually expressed as the ratios of negative and zero sequence components to the positive sequence component.

2 Voltage unbalance is considered in relation to three phase systems and negative sequence only.

3.34 Voltage Variation

Increase or decrease of root mean square (r.m.s.) voltage normally due to load variations

4 SUPPLY VOLTAGE CHARACTERISTICS

If not otherwise specified the following supply voltage characteristic are prescribed for LV, MV and HV network connections.

4.1 General

This clause prescribes the voltage characteristics of electricity at network user’s supply terminals.

In the following a distinction is made between:

a) Continuous phenomena that is, deviations from the nominal value that occur continuously over time. Such phenomena occur mainly due to load pattern; and

b) Voltage events that is, sudden and significant deviations from normal or desired wave shape.

Voltage events typically occur due to unpredictable events (for example, faults) or due to external causes (for example, weather conditions, third party actions)

The variation limits of each supply voltage characteristic are prescribed under normal operating conditions with reference to a specified parameter and in case of voltage continuous characteristics they are specified to different reference timeframes.

Measurement methods to be applied in this standard are described in IEC 61000-4-30.

Standard nominal supply voltage values are given in the IS 12360.

4.2 Continuous Phenomena

4.2.1 *Supply Voltage Frequency*

The nominal frequency of the supply voltage shall be 50 Hz. Supply voltage frequency variations shall comply with Table 1 and Table 2.

Table 1 Supply Voltage Frequency Limits for Systems with Synchronous Connection to an Interconnected System

Supply Voltage Frequency Characteristic	Reference Time Frame	Limits
Mean value of the fundamental frequency measured over 10 s	99.5 percent of each period of one year	fn ± 1 percent
	100 percent of time	fn + 4 percent / - 6 percent

Table 2 Supply Voltage Frequency Limits for Systems with No Synchronous Connection to an Interconnected System (For Example, Supply System on Certain Islands)

Supply Voltage Frequency Characteristic	Reference Time Frame	Limits
Mean value of the fundamental frequency measured over 10 s	95 percent of each period of one week	fn ± 2 percent
	100 percent of time	fn ± 15 percent

4.2.2 *Supply Voltage Variations*

Supply voltage variations in LV, MV and HV networks shall comply with Table 3, Table 4, Table 5 and Table 6 are specified with reference to:

a) Declared voltage (Uc); and

b) Mean root mean square (r.m.s) values of the supply voltage measured over 10 min.

No limits are provided for supply voltage variation for HV systems not interconnected with transmission systems.

4.2.3 *Rapid Voltage Changes*

4.2.3.1 *Single rapid voltage change*

Under consideration.

NOTES

1 Reference can be made to IEC 61000-2-2.

2 If the voltage during a change crosses the voltage dip and/or the voltage swell threshold, the event is classified as a voltage dip and/or swell rather than a rapid voltage change.

4.2.3.2 *Flicker severity*

Supply voltage flicker severity shall comply with Table 7 and is specified with reference to long term flicker severity P_{lt}.

4.2.4 *Supply Voltage Unbalance*

Supply voltage unbalance shall comply with Table 8.

Table 3 Supply Voltage Variation Limits for LV Systems Interconnected with Transmission System

Supply Voltage Characteristic	Reference Time Frame	Limits
Mean r.m.s. value of the supply voltage over 10 min	95 percent of each period of one week	Un ± 10 percent
	100 percent of time	Un +10 percent / - 15 percent

Table 4 Supply Voltage Variation Limits for MV Systems Interconnected with Transmission System

Supply Voltage Characteristic	Reference Time Frame	Limits
Mean r.m.s. value of the supply voltage over 10 min	99 percent of each period of one week	Un ± 10 percent
	100 percent of time	Un ± 15 percent

Table 5 Supply Voltage Variation Limits for LV and MV Systems Not Interconnected with Transmission System

Supply Voltage Characteristic	Reference Time Frame	Limits
Mean r.m.s value of the supply voltage over 10 min	100 percent of time	Un + 10 percent / - 15 percent

Table 6 Supply Voltage Variation Limits for HV Systems Interconnected with Transmission system.

Supply Voltage Characteristic	Reference Time Frame	Limits
Mean r.m.s value of the supply voltage over 10 min	100 percent of time	Un ± 10 percent

NOTE — According with IS 12360, network users' appliances have to tolerate supply voltages of ± 10 percent around the nominal system voltage, but generally appliances allow wider voltage variations.

Table 7 Supply Voltage Flicker Severity Limits

Supply Voltage Characteristic	Reference Time Frame	Limits
Long term flicker severity P_{lt} caused by voltage fluctuation	95 percent of each period of one week	≤ 1

Table 8 Supply Voltage Unbalance Limits

Supply Voltage Characteristic	Reference Time Frame	Limits
Ratio of root mean square (r.m.s) value of the negative phase sequence component (fundamental) to the r.m.s value of positive phase sequence component (fundamental) of the supply voltage	95 percent of each period of one week	≤ 2 percent

4.2.5 *Harmonic Voltages*

Supply voltage harmonics shall comply with Table 9 and are specified with reference to:

a) The mean root mean square (r.m.s) values of each individual harmonic voltage measured over 10 min up to the 25th harmonic order component;
b) THD up the 40th harmonic order component; and
c) The fundamental voltage (U_1).

4.2.6 *Inter Harmonic Voltages*

Under consideration.

4.2.7 *Mains Signaling Voltages*

In the supply voltage signal voltages shall be limited in accordance with Table 11 and are specified with reference to:

a) The mean values of signal voltages over 3 s; and
b) The nominal voltage (Un).

These limits are applicable for LV and MV networks.

Table 9 Supply Voltage Harmonic Limits

Supply Voltage Characteristic	Reference Time Frame	Limits
Mean root mean square (r.m.s.) values of each individual harmonic voltage measured over 10 min	95 percent of each period of one week	*See* Table 10
	Remaining 5 percent of time	No limits
THD	100 percent of time	≤ 8 percent

Table 10 Values of Individual Harmonic Voltages of the Supply Voltage in Percent of the Fundamental Voltage (U1)

Odd Multiple of Harmonics (Percent)								Even Harmonics (Percent)			
Not Multiples of 3				Odd Multiples of 3							
h (harmonic order)	LV	MV	HV	h (harmonic order)	LV	MV	HV	h (harmonic order)	LV	MV	HV
5	6	6	5	3	5	5	3	2	2	2	1.9
7	5	5	4	9	1.5	1.5	1.3	4	1	1	1
11	3.5	3.5	3	15	0.5	0.5	0.5	6 to 24	0.5	0.5	0.5
13	3	3	2.5	21	0.5	0.5	0.5				
17	2	2									
19	1.5	1.5									
23	1.5	1.5									
25	1.5	1.5									

Table 11 Signal Voltages in Supply Voltage Limits

Supply Voltage Characteristic	Reference Time Frame	Limits
Mean value of signal voltages over 3 s	99 percent of each period of one day	*See* Fig.1

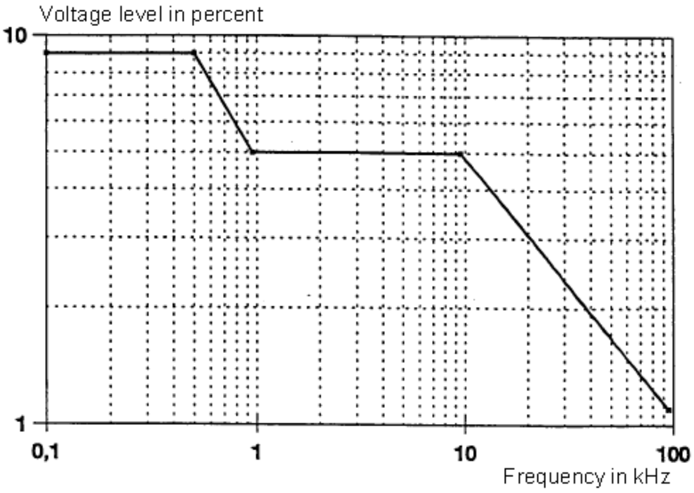

FIG.1 SIGNAL VOLTAGE LEVEL LIMITS OF SIGNAL FREQUENCIES (IN PERCENT OF UN).

4.3 Voltage Events

4.3.1 *Interruption of the Supply Voltage*

4.3.1.1 *Long voltage interruptions*

Under consideration.

4.3.1.2 *Short voltage interruptions*

Short voltage interruptions shall comply with Table 12 (number of events) and are specified with reference to:

a) Number of events per year;
b) Event duration (t); and
c) Declared voltage (Uc).

4.3.2 *Supply Voltage Dips and Swells*

Supply voltage dips shall comply with Table and are specified with reference to:

a) Number of events per year;
b) Event duration (t);
c) Residual voltage (u); and
d) Declared voltage (Uc).

Supply voltage swells shall comply with Table 14 and are specified with reference to:

a) Number of events per year,
b) Event duration (t),
c) Swell voltage (u), and
d) Declared voltage (Uc).

Table 12 Short Voltage Interruptions Limits (Number of Events Per Year) for LV and MV Networks)

Residual Voltage u (Percent)	Duration t (ms)				
	10 ≤ t ≤ 200	200 < t ≤ 500	500 < t ≤ 1 000	1 000 < t ≤ 5 000	5 000 < t ≤ 180 000
5 > u	5	20	30	10	10

NOTE — Supply voltage short interruption limits for HV networks are under consideration.

Table 13 Supply Voltage Dip Limits for LV and MV Networks in Terms of Number of Events Per Year

Residual Voltage u (Percent)	Duration t (ms)				
	10 ≤ t ≤ 200	200 < t ≤ 500	500 < t ≤ 1 000	1 000 < t ≤ 5 000	5 000 < t ≤ 60 000
90 > u ≥ 80	30	40	10	5	5
80 > u ≥ 70	30	40	5	5	5
70 > u ≥ 40	10	40	5	5	5
40 > u ≥ 5	5	20	5	5	5

NOTE

1 Supply voltage dip limits (number of events) for HV networks are under consideration.

2 For the purpose of the standard, the duration of a voltage dip is from 10 ms up to and including 1 min.

Table 14 Supply Voltage Swell Limits in Terms of Number of Events Per Year

Swell Voltage u (Percent)	**Duration t (ms)**		
	10 ≤ t ≤ 500	**500 < t ≤ 5000**	**5 000 < t ≤ 60 000**
u ≥ 120	—	—	—
120 > u ≥ 110	—	—	—

NOTES

1 Supply voltage swell limits are under consideration.

2 For the purpose of this standard, the duration of a voltage swell is from 10 ms up to and including 1 min.

The measurement of short voltage interruptions, dips and swells shall be in accordance with IEC 61000-4-30 taking into account measurement uncertainty. The post treatment shall be in accordance with IEC/TR 61000-2-8.

The following additional guidelines maybe applied:

a) For three phase four-wire connections, the line to neutral voltages shall be considered.

b) For three phase three-wire connections the line to line voltages shall be considered.

c) For single phase connections, the supply voltage (line to line or line to neutral, according to the network user connection) shall be considered.

d) A single data pair is to be recorded for each event.

e) The residual/swell voltage is respectively the lowest/maximum voltage occurring during the event.

f) The duration of the event is measured from the first instant at which the voltage falls below/above the start threshold to that at which it becomes equal to or greater/lower than the end threshold respectively.

g) The dip start threshold is equal to 90 percent of the nominal voltage; the start threshold for swells is equal to the 110 percent of the nominal voltage. The hysteresis is typically 2 percent; reference rules for hysteresis are given in 5.4.2.1 of IEC 61000-4-30 : 2009.

h) For polyphase events, a dip begins when one voltage falls below the dip start threshold and ends when all voltages are equal to or above the dip end threshold

j) For polyphase systems, an interruption occurs when the voltage falls below 5 percenet of the reference voltage on all phases, otherwise, the event is to be considered a dip.

k) For three-phase systems polyphase aggregation shall be applied which consists of defining an equivalent event characterized by a single duration and a single residual/swell voltage, in case of multiple successive events, within 1 min, time aggregation applies defining single equivalent event.

NOTE — In polyphase systems, it is advisable that the number of phases affected by each event are detected and stored.

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Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the latest issue of 'BIS Catalogue' and 'Standards: Monthly Additions'.

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